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Amphibious Technology with Adaptive Buildings in Tambakrejo for the Application of Resilience Architecture

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Abstract. The tidal flooding that occurred on the coast of North Semarang has become commonplace and always appears regularly in people's lives, such as in the Tambakrejo area. Technological advances in architecture respond to this natural condition with "Amphibious Building Systems" technology which allows buildings to float following the water level during tidal flooding. The research purpose is that buildings on the coast can apply this amphibious structural system and technology to minimise the negative impact of the tidal flood itself, and the community can adapt to natural coastal conditions. The research methods are; 1) Resilience Architecture; 2) Amphibious Technology; 3) Materials & Tools. The conclusion is that this amphibious structure and technology system can be a solution in dealing with ecological changes and natural activities on the coast. The findings of this Amphibious technology are expected to help the community stabilise the economy by providing jobs that follow the area's potential, namely pond cultivation.

Keywords: Resilience Architecture, Adaptive Buildings, Construction Systems, Amphibious Technologie*s*

INTRODUCTION

Abrasion and subsidence are among the most common natural activities in coastal areas, such as the Semarang Tambakrejo area, directly adjacent to the Java Sea. Abrasion in Tambakrejo every year always increases even though several preventive measures have been taken, such as planting mangroves and installing breakwaters. In addition, according to the Head of the Geodesy Laboratory of ITB, Dr Heri Andreas, this condition occurs due to massive groundwater exploitation [1] and is exacerbated by the fact that land subsidence in North Semarang is already very high, like Jakarta, which reaches 15-20 cm per year [2].

The sinking of several areas in Indonesia has indeed become a debate. It has made geologists make predictions about the remaining time and steps that the Government can take next to anticipate the sinking of the North Semarang Region. Launching from a statement given by the National Aeronautics and Space Administration/NASA, that if proper precautions and precautions are not taken, Semarang would only need ten years to sink and become waters [3]. From these phenomena of abrasion and land subsidence, coastal communities feel the most significant impact, namely the frequent occurrence of tidal floods once a month and the length of time it takes to recede. Natural conditions on the coast like this have been conducted research studies on amphibious design and technology. This amphibious technology allows buildings and their occupants to adapt to conditions of rising and falling sea levels, as shown in Table 1.

TABLE 1. Prior studies on Amphibious Technology and Structure

Title	Summary
Amphibious House, a Novel Practice as a Flood Mitigation Strategy in South-East Asia [4]	This research discusses concrete pontoon as the most applicable and appropriate structure for amphibious houses in Malaysia.
Amphibious Architecture and Design: A Catalyst of Opportunistic Adaptation? - Case Study Bangkok [5]	This research explores the potential role of amphibious architecture construction and design to transform Bangkok into a resilient flood city in the longer term.

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Title	Summary
Thriving with water: Developments in amphibious architecture in North America [6]	This research explains the application of amphibious technology that is effective for flood-mitigation strategy and preserve community integrity in the area.
Building Amphibious Settlements in Kampung Baru, Jakarta [7]	This research explains that applying amphibious technology in Kampung Baru can affect its resident and environmental quality of life (QOL).
Multicase Study Comparison of Different Types of Flood-Resilient Buildings (Elevated, Amphibious, and Floating) at the Vistula River in Warsaw, Poland [8]	This research compares several types of resilient flood technology by the advantages and disadvantages of applying each technology besides the river in Poland.
Building Resilience Through Flood Risk Reduction: The Benefits of Amphibious Foundation Retrofits to Heritage Structures [9]	This research explains that the buoyant foundation on amphibious technology is the solution to protect and preserve heritage buildings from floods.
Experimentation for Development for Ark'a Modulam Foundation as an Alternative to Create Amphibious Architecture in the Urban Floodplain in Kalimantan [10]	This research describes the development study amd experiment on amphibious foundation called Ark'a Modulam to find an alternative structure using plastic drum (floating material) that hopefully will be useful to create other amphibious foundations to avoid flood.

Therefore, the changing times and the spatial needs of the Tambakrejo community to adapt to these natural conditions and phenomena require a renewable solution. This research looks for new solutions that can help make it easier for people to adapt to nature. Thus, the findings of Amphibious technology can be used as design guidelines for buildings on the Tambakrejo coast to become buildings that can float and adjust to the water level. So It can handle the tidal flood, but when it is not flooded, it can be used actively according to the community's needs around the building.

THEORETICAL APPROACH

Resilience Architecture

In architecture, resilience is the ability to maintain or restore functionality when faced with events that negatively impact. Resilience is a newer and more complex form of the word sustainability, where resilience emphasises continuity and the ability of the architecture to bounce back after facing destructive disturbances. Resilience is a comprehensive combination of resilience and adaptivity in the face of changing circumstances [11].

The three parameters of resilience architecture in the book "Resilience and Development - Positive Life Adaptations" [12] include; a) Design that allows buildings to learn from the environment and adapt to various conditions, including natural disasters; b) Using the discoveries and knowledge of the previous design process including that of the maestro architect to be applied to the next design; c) Involving all aspects of life in the area and environment where the design is to be able to answer problems, as well as present the programs needed and also increase the use-value of the building.

Amphibious Technology

BACA Architects first created the Amphibious technology for its clients who have houses next to a flood-prone river. The central concept of this technology is to offer a building that stands on the ground, but when a flood arrives, the building can float according to the height of the floodwater level (Figure 1). This technology combines marine industrial construction as well as standard landed house construction. But utilises the inflow pressure of floodwater into the water storage area in the basement of the building, which is used as a driving pressure on the building so that it can float following the flood water level hydraulically [13].

This construction system is realised by providing a temporary water storage area in the basement so that when a flood arrives, the flood water would enter slowly. When the water has filled the basement, the incoming water pressure would propagate to the entire surface of the building and push the building. To float to the top to follow the water's surface, with the help of flexible poles/pipes as "support columns" that stabilise and hold the building up to 2 meters high. If the flood has receded, the building would return to its normal position, which is following the ground surface (Figure 1).

This system applies the physics theory, namely Archimedes' Law which reads: "An object is immersed in a liquid then the object would get an upward force or buoyancy force equal to the weight of the liquid displaced". A hydraulic pump that pumps floodwater when the water has entered and fills the storage space creates upward pressure on the building. This principle is also used in submarines to dive and float in the deep sea [14].

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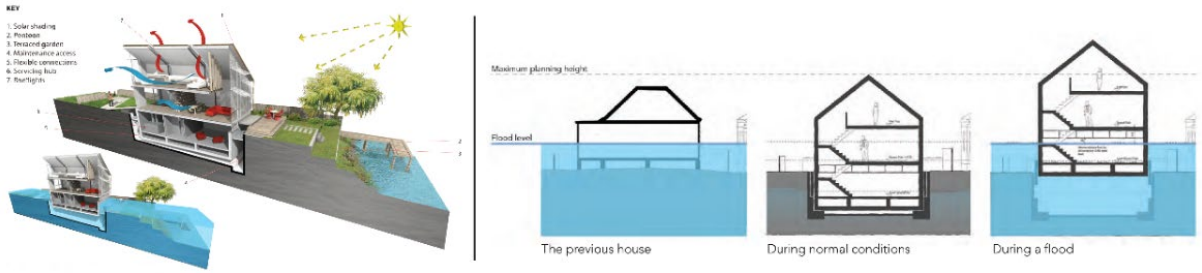

FIGURE 1. Amphibious Technology by BACA Architects
Source: BACA Architects [13], Accessed: August 09, 2021

Maintenance of the use of this construction is the same as for motorised vehicles, namely when conditions are flooded or not flooded. Testing must be carried out every six months regularly so that when needed, the machine would not malfunction or fail to float. This test is carried out by adding a height of ± 50cm to see if the building can float [13].

This Amphibious technology has many advantages to be applied to coastal areas or areas that have a high risk of frequent flooding, including; a) Can avoid flooding by floating; b) A construction system that uses mooring pipes so that the building can elevate stably with minimal literal sway; c) minimised carbon footprint; d) Can be used in areas of high density or lack of construction ground [14].

Therefore, in general, the foundation and column construction cost would be slightly higher than the construction of landed buildings. Still, this construction solution can be a new design idea that can produce adaptive buildings to natural conditions that often experience flooding, especially coastal areas with high tides and high tides constant ebb of seawater.

Material and Tools

The use of Amphibious technology requires building construction to use materials that are lightweight, resistant to water, not rust, not easily damaged, and have high buoyancy, for example, such as; a) HDPE (High-Density Polyethylene); b) B-Foam or EPS-Foam; c) Polyvinyl Carbonate (PVC) pipes; d) plastic drums; e) Stainless steel tube/beam. Styrofoam / Expanded Polystyrene (EPS) material is now in great demand in the construction of floating buildings in Indonesia. Besides being cheap, the installation and removal process is relatively more straightforward. After all material, it is a lightweight material [15].

For structural tools that are used so that the building can float on its own, utilise a hydraulic system so that several machines are needed so that the building can be lifted stably and simultaneously on the entire surface, among others; a) Hydraulic Vacuum Pumps; b) Hydraulic Lifting Platforms; c) Pressure Regulator [13]. These machines would later play a role in changing the water discharge that enters the basement into an upward thrust so that the building can float.

METHODOLOGY

Based on the theory explained on the theoretical basis, the research methods used as guidelines in this research are, among others: 1**) Resilience Architecture**; explain how to apply the concept of resilience architecture to the functions and activities of the building, so that the building can be used in dry and flood condition. 2) **Amphibious Technology**; explains how the dynamic structural system allows buildings to adapt to the tidal flood disaster by floating and when the water is receding can back to it place on the ground. 3) **Materials and Tools**; explain materials and tools as a compliment and supporting structures used in buildings to float when the water is rising.

RESULT AND DISCUSSION

Based on the location of the building in an area that has locality values for milkfish cultivation in ponds (Figure 2). The main idea of this research is to produce adaptive buildings that pay attention to the local aspects of Tambakrejo. Namely, making buildings useful for the community during high and low tides to sell souvenirs and processed

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milkfish. In addition, if during a flood, it can be used as a place of refuge. At low tide, this floodwater is accommodated in ponds or stored to be processed as water in the toilet (Re-use Water Systems).

FIGURE 2. Site Plan
Source: Author , 2021

1. Resilience Architecture

The application of Resilience Architecture in this design can be seen from how the building can adapt to the surrounding natural conditions while still involving economic and local aspects that already existed and developed previously. This floating building design with Amphibious technology benefits the coastal community of Tambakrejo, whose economy becomes uncertain because every month it is constantly hit by tidal floods, which have a relatively long receding time. So that the economic and daily activities of the community are hampered and not optimal.

The existence of this adaptive building increases the effectiveness and mobility of the Tambakrejo community in carrying out economic activities so that it is expected to make the Tambakrejo community more prosperous. The building is adaptive so that both at high tide and low tide, it can still be active to be used as a dynamic space function according to community needs. This technology allows buildings to reuse and save water because tidal floodwater that previously entered the basement storage area as "floating media" can be filtered to be used as irrigation water in ponds or used for toilet water (Figure 3).

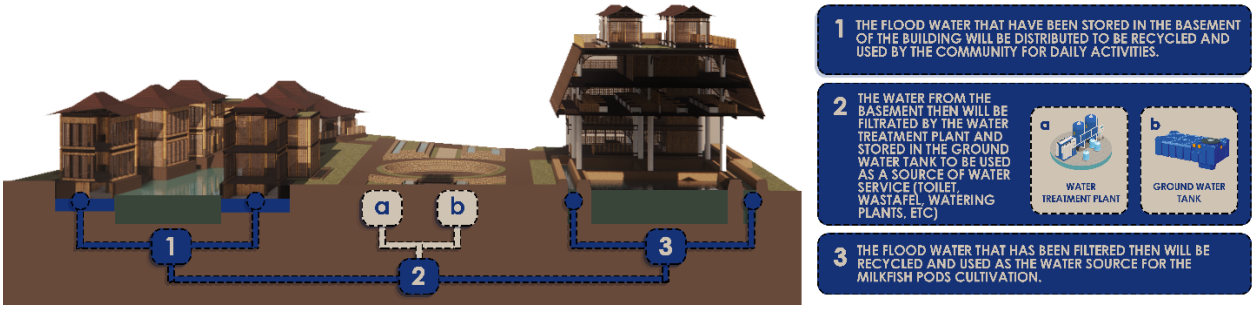

FIGURE 3. Rob Flood Water Reuse Scheme in Buildings
Source: Author , 2021

2. Amphibious Technology

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At low tide, the building would stand like a building in general in the same level with the ground (landed building). When it's on the ground, the hydraulic lifting platform will be folded and the structure will be on standby mode to face any sudden flood that might happen. Still, when the tidal flood or rain arrives, the water would enter the storage area in the basement of the building through the iron grille holes around the building. Then, when the flood water that enters the basement has a height that exceeds 50cm, the building would start to float, and the necessary machines must be turned on, such as; a) Hydraulic Vacuum Pump as a controller for the entry and exit of floodwater so that the pressure can be used as a compressive force to the top of the building; b) Pressure Regulator to stabilise pressure and transmit it to all parts of the building surface; c) Hydraulic Lifting Platform to help the building rise and the entire platform so that it can lift it is entirely simultaneously (not tilted to one side) as well as a safety so that during low tide the building can descend slowly and not descend quickly (Figure 4).

The foundation construction is reinforced with steel columns (deep galvanise) that use a sleeve system, where the outermost layer is permanently placed in the soil to keep the building strong and durable at a certain point and does not shift. Then, the smaller inner layer is a dynamic building column (can move up and down) to secure the building structure.

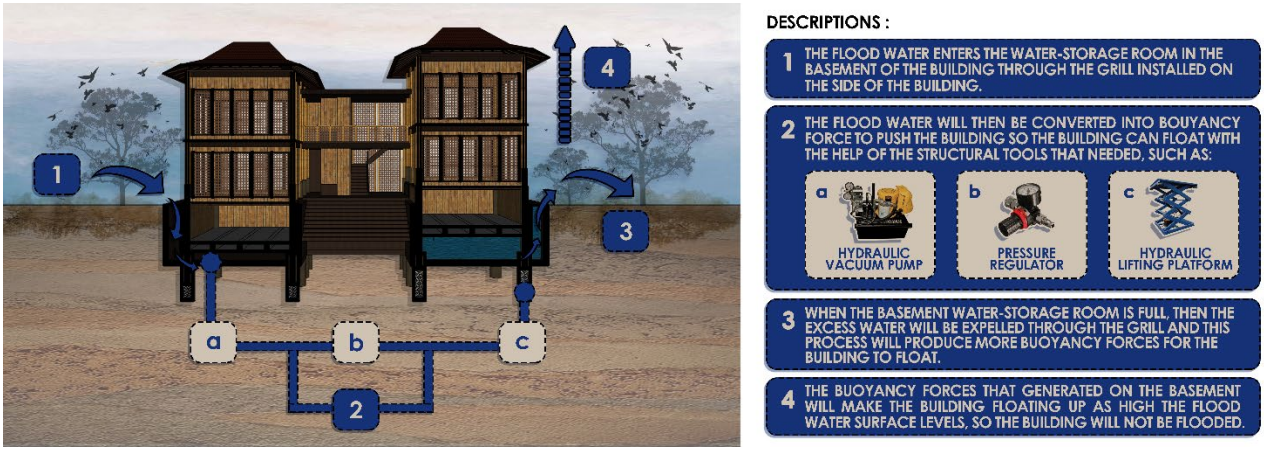

FIGURE 4. Amphibious Technology Work System Schematic
Source: Author, 2021

3. Material and Tools

The material used in this building is sturdy, lightweight, and easy to find in the Tambakrejo residential location and is not easily weathered by water. These materials include; a) B-Foam or EPS-Foam Double Panel as a "float" or lightweight plate made of a combination of Styrofoam with concrete which has a lightweight, but is solid and also has high buoyancy; b) EPS-Foam Single Panel as a massive wall in the building, so that the structure becomes lightweight and floats; c) Foam Cement as a floor plate on the second floor made of Styrofoam so that it is lightweight; d) Bamboo as a connecting column for the construction of the first and second-floor buildings with a connection using bamboo pens and fibres as one of the local materials that characterise Tambakrejo; e) Finishing material: Water Repellent Paint or Calcium Ciliate Board as a safety layer of water added so that the structure can be stronger and not easily weathered or corroded (Figure 5).

In addition to structural materials, several structural tools are needed to lift buildings during floods made of stainless steel and rust-resistant, including; a) Hydraulic Vacuum Pumps; b) Pressure Regulators; c) Hydraulic Lifting Platforms.

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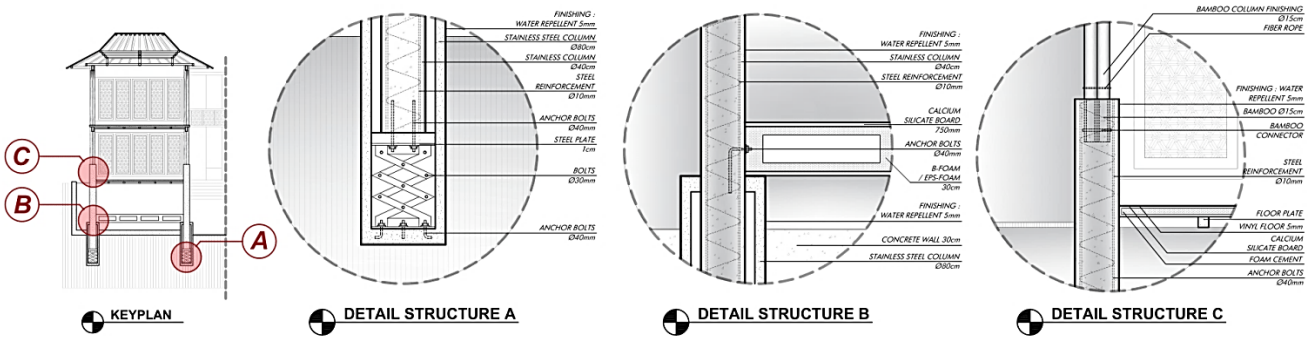

FIGURE 5. Details of the Amphibious Construction Structure on the building
Source: Author, 2021

CONCLUSION

Climate change and natural phenomena experienced by humans continue to increase every year. It also occurs in the Java Sea coastal area, which is faced every year, even experiencing land subsidence of up to 15-20cm. This tidal flood condition makes a phenomenon of natural activities that always occur and are felt by the people of Tambakrejo almost every month. As a result of this phenomenon, coastal communities are affected by tidal flooding. Hence, they need solutions and innovations that need to be found to solve problems, to be able to help communities adapt to rising tides.

Architectural solutions that will answer the phenomena that occur in Tambakrejo or other areas prone to flooding. Use of Amphibious Technology or adaptive buildings that can float during tidal flooding caused by tides. The construction of this building utilises technological developments while maintaining the locality value of Tambakrejo. So, with the use of sturdy but lightweight materials such as bamboo, B-Foam or EPS-Foam (made of Styrofoam) and assistance from machines, such as; a) Hydraulic Vacuum Pumps; b) Pressure Regulators; c) Hydraulic Lifting Platforms. This building technology can float when there is a tidal flood by following the sea level, but at low tide, the building would be above the ground like buildings in general.

The findings of this Amphibious technology are expected to help the community stabilise the economy by providing jobs that follow the area's potential, namely pond cultivation. And it can improve the quality of life of the people of Tambakrejo because they no longer have to be disturbed by their daily activities due to tidal flooding. So this finding can also be a sustainable design solution because flood water is accommodated to float buildings. After being water filtered, this floodwater would be reused to meet the water needs of aquaculture ponds and the daily water needs of the building (Re-use Water Systems).

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